1. Name of Experiment/Project/Collaboration: **ANNIE: Accelerator Neutrino Neutron Interaction Experiment**

2. Physics Goals

    a. Primary: **Measure final-state neutron abundance from neutrino interactions in water, as a function of q^2 and categorized by interaction type (CCQE, NC, resonant pion, etc)**

    b. Secondary: **Cross-sections of various non-QE neutrino interactions in water**

3. Expected location of the experiment/project: **FNAL - SciBooNE Hall**

4. Neutrino source: **Booster Neutrino Beam (BNB)**

5. Primary detector technology: **advanced water Cherenkov detector ("optical TPC")**

6. Short description of the detector: **Gd-loaded water volume, instrumented with Large Area Picosecond Photodetectors (LAPPDs) and conventional PMTs. Muon range detector to measure lepton angle and energy. Possibility of runs with water-based liquid scintillator and magnetized MRD.**

7. List key publications and/or archive entries describing the project/experiment.

    ANNIE Expression of Interest: arXiv:1402.6411 [physics.ins-det]

    ANNIE Letter of Intent (Fermilab P-1063): available at annie.uchicago.edu

8. Collaboration

    a. Institution list: **ANL, BNL, FNAL, Imperial College London, IA State, Johns Hopkins, OH State, Purdue, Ultralytics (LLC), UC Davis, UC Irvine, MIT, U Chicago, U Hawaii, Queen Mary University of London**

    b. Number of present collaborators: **33**

    c. Number of collaborators needed: **40-50**

9. R&D

    a. List the topics that will be investigated:

        i. **detailed track reconstruction using precision measurements of photon hits with sub-nanosecond, cm-level imaging capabilities**

        ii. **operation of LAPPDs in water**

        iii. **fast, low-power sampling electronics**

        iv. **neutron tagging in a high-E beam**

        v. **other water enhancements (water based liquid scintillator)**

b. Which of these are crucial to the experiment: **i-iv**

c. Time line: **3-4 years**

d. Benefit to future projects

   i. **Background reduction estimates and fake rates for future proton decay and SN detection efforts using Gd-loaded water or water-based LS.**

   ii. **New constraints on neutrino interaction models used to understand backgrounds and systematics on future oscillation experiments.**

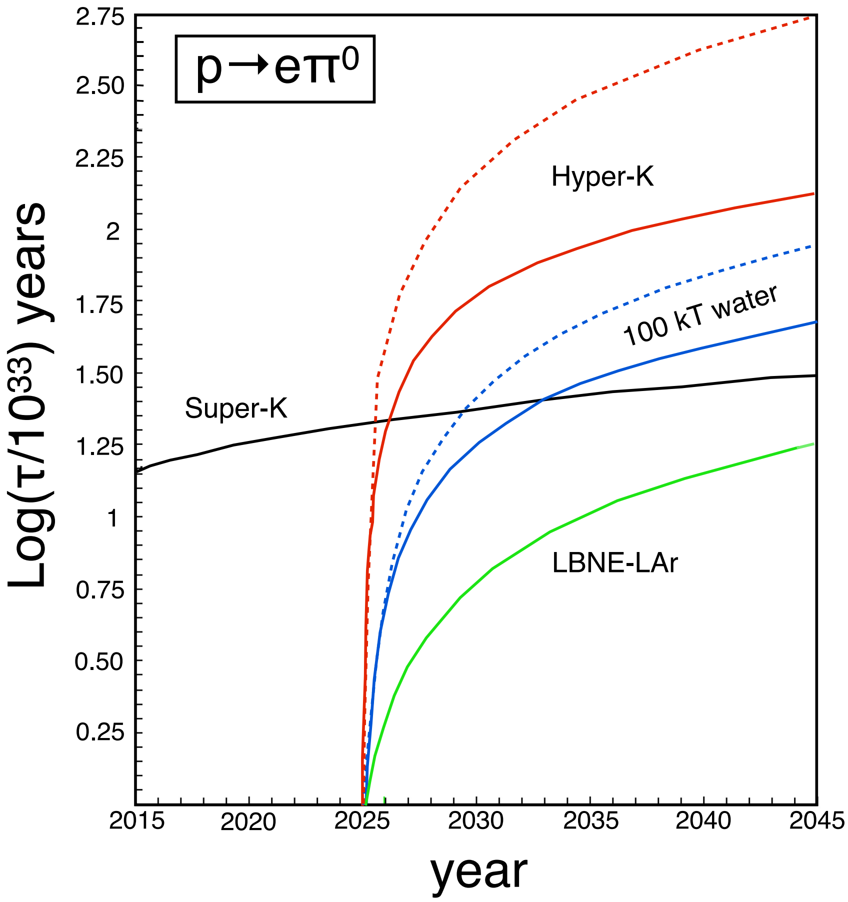
   iii. **A new, complementary technological path for neutrino detection as part of the US neutrino program.**

10. Primary physics goal expected results/sensitivity:

    a. **The main physics goal of ANNIE is to measure final state neutron abundance from 500 MeV to 3 GeV range for neutrino interactions. Since atmospheric neutrino interactions in this energy range contribute the dominant background to proton decay detection, these backgrounds could potentially be rejected on the the basis of any final state neutrons. These GeV-scale neutrino interactions might often produce neutrons, while proton decays only rarely do. In order to quantify exclusion limits, and determine how many candidates are needed for discovery, one needs to understand atmospheric neutrino fake rates at the percent level. Proton decay sensitivity varies significantly with this yet unknown background rejection capability (see figure below). Estimating background rejection depends on both the neutron detection efficiency and on the probability of neutron yields. These uncertainties also affect a number of other possible neutrino measurements which could benefit from neutron tagging (relic super nova neutrinos, neutrino sign discrimination).**

    Note that tree-level neutrino-nucleon interactions will produce exactly 1 or 0 neutron. We will thus measure the potential excess generated by a variety of multi-scale nuclear processes (secondary nucleon scattering, meson exchange currents [MEC], pion absorption, nuclear de-exitation by neutron emission, secondary scattering). These processes can enhance the probability of single neutron production, and the probability of events with multiple final-state neutrons. For estimating background reduction from neutron tagging in physics analyses and for testing various nuclear models, it suffices to measure the probability of events with 0,1,2, and >2 neutrons. We estimate that O(10^4) events will be adequate to estimate these probabilities to within a few percent. This can be achieved by a year of running in the BNB with tight fiducial cuts restricting the volume to 1 ton.

    Additional statistics will allow us to bin these data by the reconstructed q^2, and separated into CC-QE, CC resonant pion, NC, etc. The needed statistics for more detailed measurements are currently under study, but we believe this can be achieved with a second year of running, and a looser fiducial cut.



b. List other experiments that have similar physics goals: **There are no other experiments with the same physics goals. The physics goals of ANNIE fit well within a coherent program that includes experiments with significant (current and potential) US participation: WATCHMAN, Super-K, Hyper-K, Advanced Scintillator Detector Concept (ASDC).**

11. Secondary Physics Goal

    a. Expected results/sensitivity

    b. List other experiments that have similar physics goals

12. Experimental requirement

    a. Provide requirements (neutrino source, intensity, running time, location, space,…)for each physics goal:

        i. **>10k interactions per ton per year in water, over an energy range from 0.2-4.0 GeV, peaked at around 1 GeV**
        ii. **low pileup**

13. Expected Experiment/Project time line
    a. Design and development: **Development work is currently under way. Phase I planning will be complete by Summer 2015. Optimization of the full detector for phase II (first physics run) will be finished by Spring of 2016.**
    b. Construction and Installation: **Construction will be phased: We intend to install the tank with conventional PMTs by September 2015. Commissioning of the LAPPD system and refurbished Muon Range Detector would occur in September of 2016.**
    c. First data: **Background measurements will begin in Fall of 2015. First physics run would start in Fall of 2016.**
    d. End of data taking: **Fall of 2018.**
    e. Final results: **Fall of 2018.**
14. Estimated cost range
    a. US contribution to the experiment/project:
        i. **PHASE I: $50k (equipment and materials only)**
        ii. **PHASE II and III:**
            1. **LAPPD development for Water: $100k (overlap with WATCHMAN and ASDC)**
            2. **LAPPD acquisition: ~$200k**
15. The Future
    a. Possible detector upgrades and their motivation:
        i. **The addition of water-based liquid scintillator would provide extra sensitivity to particles below Cherenkov production threshold. It would also contribute to the general water-based scintillator R&D program. The implementation of a magnetized MRD would enable an additional handle for neutrino sign discrimination.**
    b. Potential avenues this project could open up.
        i. **New technological options for the long-baseline neutrino program, involvement of new collaborators, new physics techniques.**